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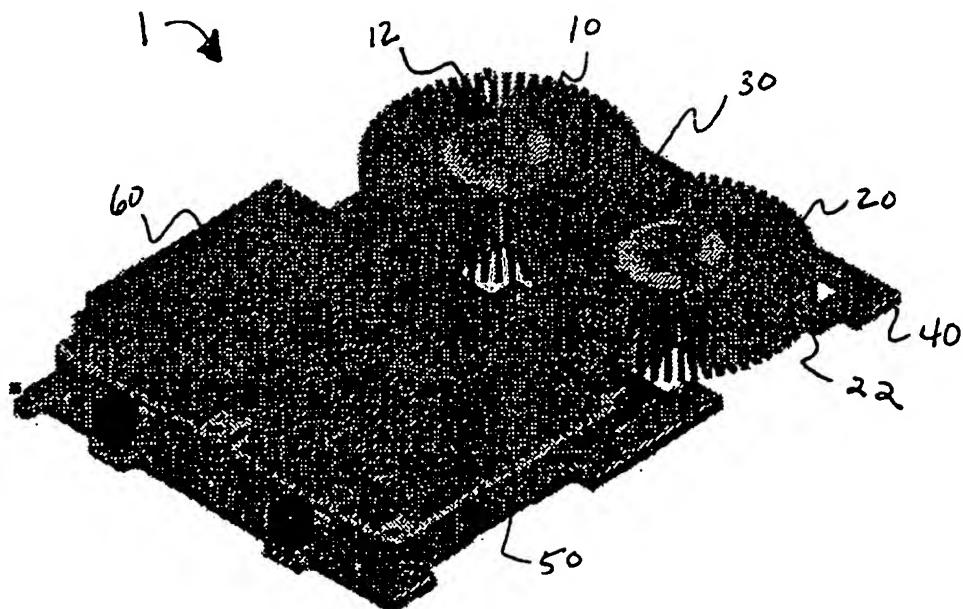
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[Continued on next page]

(54) Title: COOLING SYSTEM HAVING INDEPENDENT FAN LOCATION



WO 03/030608 A1



(57) Abstract: The present invention comprises a heatsink adjacent a first device wherein a gas supply can be located to provide gas in any direction with respect to the heatsink. The gas supply may be realized as a fan, a blower, or a compressed gas source. The gas supply may be provided in any direction or in multiple directions. The heatsink is in thermal communication with a first heat-producing device such as a microprocessor. In a preferred embodiment the heatsink comprises a radial shaped folded fin heatsink arranged for axial flow.



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- *as to the identity of the inventor (Rule 4.17(i)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)*
- *as to the applicant's entitlement to claim the priority of the earlier application (Rule 4.17(iii)) for all designations*
- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii)) for the following designations AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, OM, PH, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW, ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG)*

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## Cooling System Having Independent Fan Location

### FIELD OF THE INVENTION

5        The present invention relates generally to cooling systems and more particularly to cooling systems for use with integrated circuits (ICs) and printed circuit boards.

### BACKGROUND OF THE INVENTION

10       As is known in the art, there is a trend to reduce the size of semiconductor devices, integrated circuits and microcircuit modules while at the same time having the devices, circuits and modules perform more functions. To achieve this size reduction and increased functionality, it is necessary to include a greater number of active circuits, such as transistors for example, in a given unit area. As a consequence 15       of this increased functionality and dense packaging of active devices, such devices, circuits and modules (hereinafter collectively referred to as "circuits") use increasingly more power. Such power is typically dissipated as heat generated by the circuits.

20       This increased heat generation coupled with the need for circuits to have increasingly smaller sizes has led to an increase in the amount of heat generated in a given unit area. To further exacerbate the problem, the circuits are often densely mounted on printed circuit boards.

25       This increase in the amount of heat generated in a given unit area has led to a demand to increase the rate at which heat is transferred away from the circuits in order to prevent the circuits from becoming damaged or destroyed due to exposure to excessive heat. To increase the amount of heat that such circuits can withstand, the circuits can include internal heat pathways that channel or otherwise direct heat away 30       from the most heat-sensitive regions of the circuits.

Although this internal heat pathway technique increases the amount of heat which the circuits can withstand while still operating, one problem with this internal

heat pathway technique is that the amount of heat generated by the circuits themselves often can exceed the amount of self-generated heat which the circuits can successfully expel as they are caused to operate at higher powers. Furthermore, other heat generating circuit components mounted on printed circuit boards proximate the 5 circuits of interest further increase the difficulty with which heat can be removed from heat sensitive circuits. Thus, to increase the rate at which heat is transferred away from the circuits, a heatsink is typically attached to the circuits.

Such heatsinks typically include a base from which project fins or pins. The 10 fins or pins are typically provided by metal extrusion, stamping or other mechanical manufacturing techniques. The heatsinks conduct and radiate heat away from the heat generating and thermally vulnerable regions of circuits. To further promote the heat removal process, fans are typically disposed adjacent the heatsink to blow or otherwise force air or gas through the sides of the fins or pins of the heatsink.

15

One problem with this approach, however, is that the amount of air or other gas which a fan or blower can force through the heatsink fins/pins is limited due to the significant blockage of gas flow pathways due to the fins/pins themselves. Furthermore, in a densely populated printed circuit board (PCB) or multi-circuit 20 module (MCM), other circuit components and mechanical structures required to provide or mount the PCB or module present additional blockage to gas pathways and also limits the amount of gas flow through the heatsink thus limiting the effectiveness of the heatsink. Thus, the ability of such conventional heatsinks and heatsink fan assemblies is limited and is not sufficient to remove heat as rapidly as necessary to 25 ensure reliable operation of state of the art devices, circuits and modules having increased thermal cooling requirements.

Another problem associated with earlier heat removal systems is that the gas supply source had to be in linear alignment with the device being cooled, and was 30 typically provided along only a single side of the heat removal device. This further limits the ability to provide redundancy if one of the gas supply sources should malfunction.

It would, therefore, be desirable to provide a cooling system that is capable of removing an amount of heat that is greater than the amount of heat removed by conventional cooling systems. Additionally, it would be desirable to provide the a cooling system which does not have a linear dependency requirement between the 5 heatsink and the gas supply source so that the gas supply source could be positioned at any direction with respect to the heatsink, and such that redundancy for the gas supply source can be easily and effectively incorporated into the heat removal system.

## SUMMARY OF THE INVENTION

10 In accordance with the present invention, a cooling system comprises a first heatsink adjacent a first device and wherein a gas supply can be located to provide gas in any direction with respect to the heatsink. The gas supply may be realized as a fan, a blower, or a compressed gas source. The gas supply may be provided in any direction or in multiple directions. The heatsink is in thermal communication with a 15 first heat-producing device such as a microprocessor. In a preferred embodiment the heatsink comprises a radial shaped folded fin heatsink arranged for axial flow.

## BRIEF DESCRIPTION OF THE DRAWINGS

20 The foregoing features of this invention, as well as the invention itself, may be more fully understood from the following description of the drawings in which:

Figure 1 is an isometric view side view of a first embodiment of a cooling system having independent fan location;

Figure 2 is an isometric view of the cooling system of Figure 1 including a pair of blowers;

25 Figure 3 is an isometric view of the cooling system of Figure 2 including a housing;

Figure 4 is another embodiment of a cooling system having independent fan location including four blowers;

30 Figure 5 is an isometric view of the cooling system of Figure 4 including a housing;

Figure 6 is another embodiment of a cooling system having independent fan location including eight fans; and

Figure 7 is an isometric view of the cooling system of Figure 6 including a housing.

#### DETAILED DESCRIPTION OF THE INVENTION

5 Referring now to Figures 1-7 in which like elements are provided having like reference designations throughout the several views, a cooling system having independent fan location is shown in Figure 1. The cooling system 1 includes a first axial heatsink 10. While additional heatsinks are shown in this figure, the first axial heatsink can function itself as the cooling system having independent fan location. A  
10 10 cooling gas supply source, such as a blower, fan, or compressed gas source, can be provided to axial heatsink 10 from any direction, as long as the gas exiting the gas supply source impinges on the fins of the axial heatsink. In this particular embodiment, a pair of axial heatsinks 10 and 20 are provided disposed adjacent one another. Each of the heatsinks is thermally coupled to respective devices, and provide  
15 for removal of heat from the devices. A sidewall of the heatsink fin may further include at least one aperture extending through the sidewall. The apertures may be provided in a predetermined pattern, shape and size to provide the desired cooling. The top edges of the fins may be closed, and the bottom edges of the troughs may also be closed, thereby allowing the fin/trough combination to act as a plenum.

20 20 Each axial heatsink may further include a thermally conductive member 12 and 22. A first surface of the member is adapted to be in contact with an active portion of a heat-generating device (e.g. an integrated circuit). Thus the folded fin stock is wrapped around the member and is in thermal communication with the member. Typically, the folded fin stock and member are provided from tinned copper  
25 or aluminum.

30 Ideally, the portion of the member in contact with the heat-generating device is provided having a shape that covers as much as possible the active area of the heat-generating device. In one embodiment, the member is machined flat and a thermal interface material is disposed on the surface of the member which will be in contact with the heat generating device. Thus, for example, in the case where the heat-

generating device is an IC which itself includes an internal heatsink, the member should cover the internal heatsink of the IC.

Also, it may be desirable or necessary to provide folded fin members of the 5 heatsink as a single unitary piece or as more than one piece. The particular number of pieces from which the first heatsink is provided may be selected in accordance with a variety of factors including but not limited to the particular application, the amount of heat which must be transferred away from heat generating devices, the amount of space available for mounting of the heatsink and other components, the particular 10 material from which the heatsink pieces is provided, the particular manufacturing techniques used to fabricate heatsink and the cost of manufacturing the heatsink.

In order to prevent the fins of the heatsinks from interfering with each other or otherwise overlap, a section 30 has been removed from each axial heatsink to allow 15 the heatsinks to be mounted within frame 40. In the depicted embodiment a same amount of material (approximately 25 percent maximum for a selected set of fins) has been removed from each axial heatsink. In another embodiment the amount removed from one heatsink could be more than the amount removed from the other heatsink, especially if the heatsink having the most fin material removed was disposed on a 20 device providing less heat than the device on which the other axial heatsink is disposed. Additionally, after the cut is made into the heatsink to remove some material, such as by using electric discharge milling (EDM), when the fins include a plurality of holes such that the fins act as plenums, it is desirable to seal the open ends of the cut fins after they have been machined by the EDM procedure.

25 The particular embodiment shown in Figure 1 further includes a pair of linear heatsinks 50 and 60. Linear heatsinks 50 and 60 are coupled to respective second devices. While the linear heatsink is shown having a generally rectangular shape, other shapes could also be used. These linear heatsinks may be realized as standard 30 folded fin heatsinks and in this embodiment are used to cool devices that provide power to the devices cooled by axial heatsinks 10 and 20.

The axial heatsinks 10, 20 and the linear heatsinks 50,60 may be coupled to any type of integrated circuit package including, but not limited to, dual-in-line packages (DIP) leadless chip carriers, leaded chip carriers, flat packs, pin-grid arrays as well as other surface mount packages and small outline integrated circuit packages 5 for surface-mounting.

The heatsinks as shown and described herein may be disposed over a first surface of an integrated circuit that is disposed on a printed circuit board. Disposed between a first surface of a circuit and a first surface of a heatsink is a sheet of a 10 thermally conductive matrix material. The matrix material facilitates an extraction of heat from the circuit to the heatsink.

It should also be noted that in some applications it might be desirable to mount the circuit on the printed circuit board prior to placing the heatsink/thermally 15 conductive matrix material assembly on to the circuit. It should also be noted that in some applications it might be desirable to apply the thermally conductive matrix material first to the surface of the circuit and then to mount the heatsink to the circuit/thermally conductive matrix assembly and then mount the assembly on the PCB.

20 Referring now to Figure 2, the assembly of Figure 1 is shown along with a pair of blowers 70 and 80. In a preferred embodiment, the blower comprises a "squirrel cage" type blower. Blower 70 and blower 80 are similar, however blower 80 has been inverted with respect to blower 70. As is known in the art, blowers typically have a 25 non-uniform velocity profile at their output. Accordingly, blower 80 has been inverted in order to provide its maximum gas velocity directly to heatsink 20, since both blowers 70 and 80 are single-sided blowers. Alternately a left rotation blower and a right rotation blower could have been used. The distance between the blower and the axial heatsink is chosen to provide a more uniform flow to the heatsink. 30 Blower 70 is arranged to provide cooling gas to heatsink 10 while blower 80 is disposed to provide cooling gas to heatsink 20. In the event that one of the blowers fails, non-uniform cooling would result as gas would leak back through the failed blower.

Referring now to Figure 3, the assembly of Figure 2 is shown further comprising a housing 90 disposed over the heatsinks. Housing 90 provides a cover extending from blowers 70 and 80, over the axial heatsinks (not shown) and over the 5 linear heatsinks (not shown). Additionally, housing 90 may be provided with a plurality of vanes. The vanes may be located at a first end of the housing, where the blowers interface to the housing. Additionally vanes may be provided at an area of the housing that corresponds to the space between the axial heatsinks and the linear heatsinks. The vanes are designed to reduce the turbulence within the housing, 10 prevent or reduce air boundary separation within the housing, and to maintain the velocity head pressure. The vanes minimize the discontinuities in the airflow through the housing. As a result, a high pressure, generally uniform stream of gas is provided through the housing. The vanes are preferably solid pieces having a smooth finish in order to minimize turbulence. Transition vanes may also be incorporated at the end of 15 the housing.

Housing 90 may further include flapper valves at the first end thereof. The gas stream resulting from an operational blower would keep the flapper valve in the open position. The flapper valves would be biased to a closed position when a blower 20 fails, thereby preventing back leakage of cooling gas through the failed blower.

Referring now to Figure 4, the assembly of Figure 2 is shown with two additional blowers 75 and 85. Due to the radial design of heatsinks 10 and 20, cooling gas can be provided from any direction. Accordingly, there is no linear relationship 25 dependency between the blower(s) and the remainder of the assembly.

The fact that the blowers can be positioned anywhere around the radial heatsinks provides great flexibility in the design and layout of devices, as well as providing for redundancy. For example, blower 75 can be used as a redundant blower 30 with respect to blower 70. Thus, if blower 70 malfunctions, blower 75 can be enabled and provide the same supply of gas as that provided by blower 70. Blower 85 can be used in a similar manner to provide redundancy for blower 80. Alternately, blowers 70 and 80 could be used to provide redundancy for blowers 75 and 85 respectively. Additionally, all four blowers 70, 75, 80 and 85 can be used at the same time to

provide cooling gas to the heatsinks 10 and 20. Since the blowers can be provided in any direction adjacent to the heatsinks, multiple blowers can be easily and effectively implemented.

5 Referring now to Figure 5, the assembly of Figure 4 is shown further comprising a housing 95 disposed over the heatsinks. Housing 95 provides a cover extending from blowers 70, 75, 80 and 85, over axial heatsinks 10 and 20 and over linear heatsinks 50 and 60. Additionally, housing 90 may be provided with a plurality of vanes. The vanes may be located where the blowers interface to the housing.  
10 Additionally vanes may be provided at an area of the housing, which corresponds to the space between the axial heatsinks and the linear heatsinks. Transition vanes may also be incorporated at the end of the housing.

15 Housing 95 may further include flapper valves at the blower interfaces. The air stream resulting from an operational blower would keep the flapper valve in the open position. The flapper valves would be biased to a closed position when a blower fails, thereby preventing back leakage of cooling gas through the failed blower.

20 Referring now to Figure 6, a heat sink assembly is shown with a plurality of fans. The first plurality of fans 100 provides gas to the assembly. The second plurality of fans 110 removes gas from the assembly 1. Multiple fans may be required to achieve the desired cooling. Fans could also be disposed about the sides of axial heatsinks 10 and 20.

25 Figure 7 shows the assembly of Figure 6 further comprising a housing 120. Housing 120 provides a cover extending from the first plurality of fans 100, over axial heatsinks 10 and 20 and over linear heatsinks 50 and 60 and extending to the second plurality of fans 110. Additionally, housing 90 may be provided with a plurality of vanes. Housing 95 may further include flapper valves at the fan interfaces. The air stream resulting from an operational fan would keep the flapper valve in the open position. The flapper valves would be biased to a closed position when a fan fails, thereby preventing back leakage through the failed fan. By use of a plurality of fans, in the event one fan fails the system is not significantly affected since, due to the

combination of fan curves, only an approximately four percent reduction is realized in the event of a fan failure.

Having described preferred embodiments of the invention it will now become apparent to those of ordinary skill in the art that other embodiments incorporating these concepts may be used. Accordingly, it is submitted that that the invention should not be limited to the described embodiments but rather should be limited only by the spirit and scope of the appended claims.

## CLAIMS

What is claimed is:

5     1.     A cooling system comprising:  
          a first group of at least one heatsink; and  
          a first gas supply disposed proximate said first group of at least one heatsink  
and positionable in any direction with respect to said first group of at least one  
heatsink, said gas supply capable of providing cooling gas to said first group of at  
10    least one heatsink.

2.     The cooling system of claim 1 wherein said first group of at least one heatsink  
includes a first heatsink and a second heatsink, said second heatsink disposed adjacent  
said first heatsink.

15    3.     The cooling system of claim 2 wherein at least one of said first heatsink and  
said second heatsink have a section removed such that said first heatsink does not  
overlap with said second heatsink.

20    4.     The cooling system of claim 3 wherein first heatsink and said second heatsink  
has approximately the same amount of material removed therefrom.

5.     The cooling system of claim 1 wherein said first gas supply is selected from  
the group including fans, blowers and compressed gas sources.

25    6.     The cooling system of claim 1 wherein at least one heatsink of said first group  
of at least one heatsink comprises a radial heatsink.

7.     The cooling system of claim 1 further comprising a second group of at least  
30    one heatsink, said second group of at least one heatsink disposed adjacent said first  
group of at least one heatsink.

8. The cooling system of claim 7 wherein at least one heatsink of said second group of at least one heatsink comprises a linear heatsink.

9. The cooling system of claim 1 further comprising a housing disposed over at least a portion of said first group of at least one heatsink and extending to said first gas supply.

10. The cooling system of claim 10 said housing further extends over at least a portion of said second group of at least one heatsink.

10

11. The cooling system of claim 9 wherein said housing includes at least one flapper valve disposed adjacent said first gas supply, said flapper valve movable between an open position when said first gas supply is providing gas to said first group of at least one heatsink and a closed position when said first gas supply is not providing gas to said first group of at least one heatsink.

12. The cooling system of claim 1 further comprising a second gas supply, said second gas supply positionable in any direction with respect to said first group of at least one heatsink, said second gas supply capable of providing cooling gas to said first group of at least one heatsink.

20

13. The cooling system of claim 12 wherein said second gas supply is operational in the event said first gas supply becomes inoperable.

25

14. The cooling system of claim 13 further comprising a housing disposed over at least a portion of said first group of at least one heatsink and extending to said first gas supply and said second gas supply.

30

15. The cooling system of claim 1 wherein said second gas supply is selected from the group including fans, blowers and compressed gas sources.

16. The cooling system of claim 14 wherein said housing further comprises:

5 a first group of at least one flapper valve disposed adjacent said first gas supply, said first group of at least one flapper valve movable between an open position when said first gas supply is providing gas to said first group of at least one heatsink and a closed position when said first gas supply is not providing gas to said first group of at least one heatsink; and

10 a second group of at least one flapper valve disposed adjacent said second gas supply, said second group of at least one flapper valve movable between an open position when said second gas supply is providing gas to said first group of at least one heatsink and a closed position when said second gas supply is not providing gas to said first group of at least one heatsink.

17. The cooling system of claim 1 further comprising a gas removal assembly disposed proximate said first group of at least one heatsink, said gas removal assembly capable of removing gas from said first group of at least one heatsink.

15

18. The cooling system of claim 17 wherein said gas removal assembly comprises at least one fan.

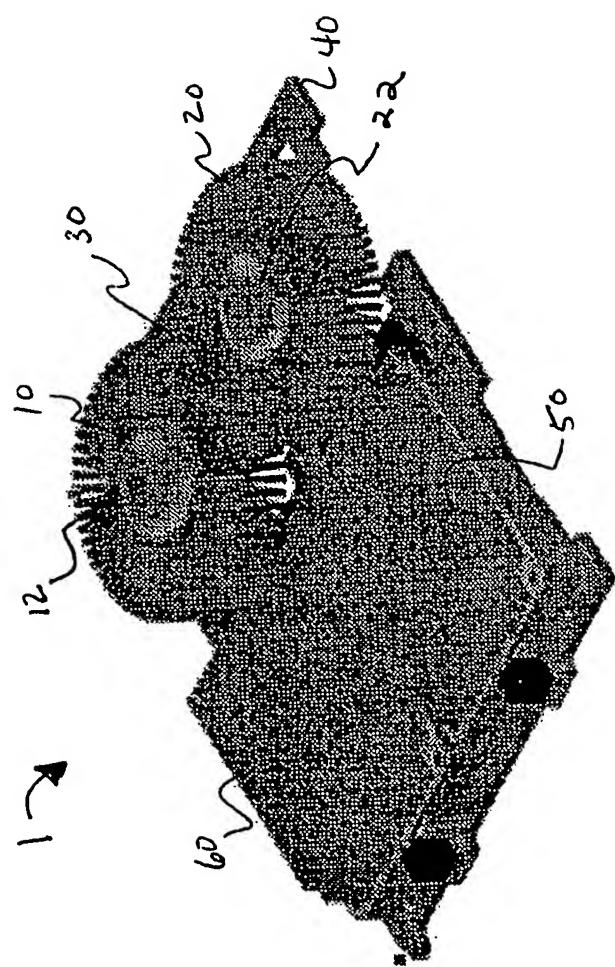


FIGURE 1

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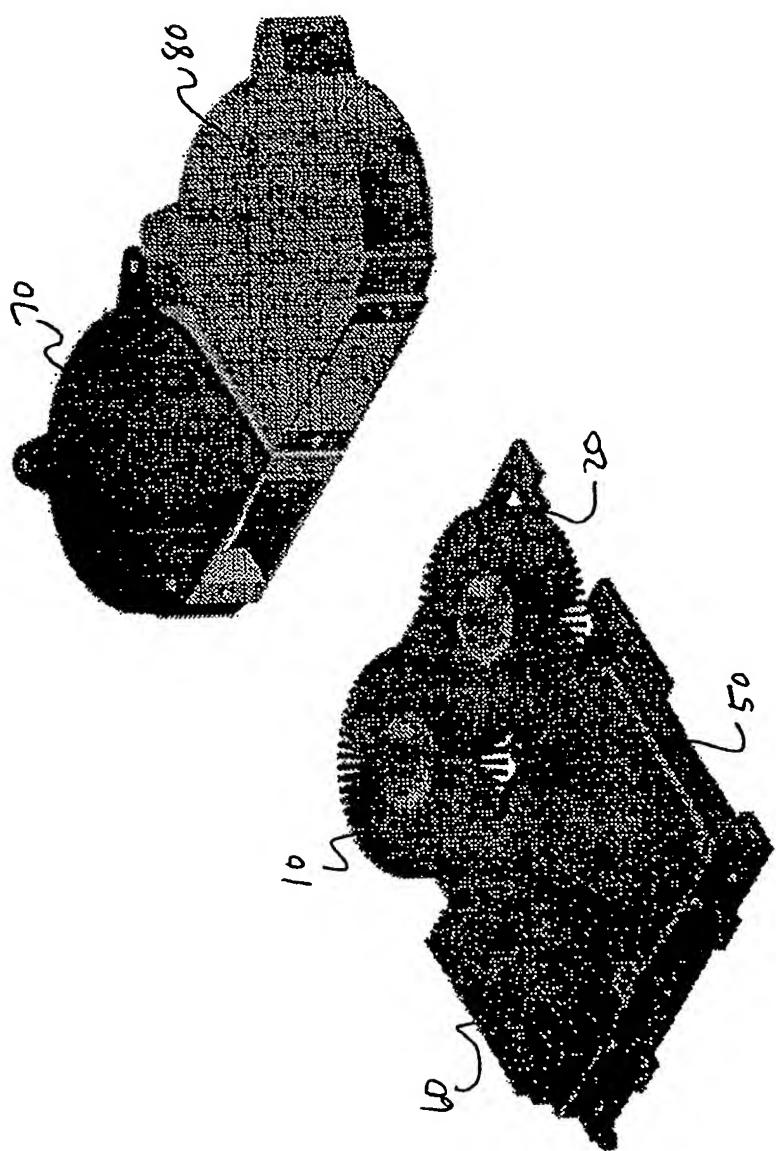
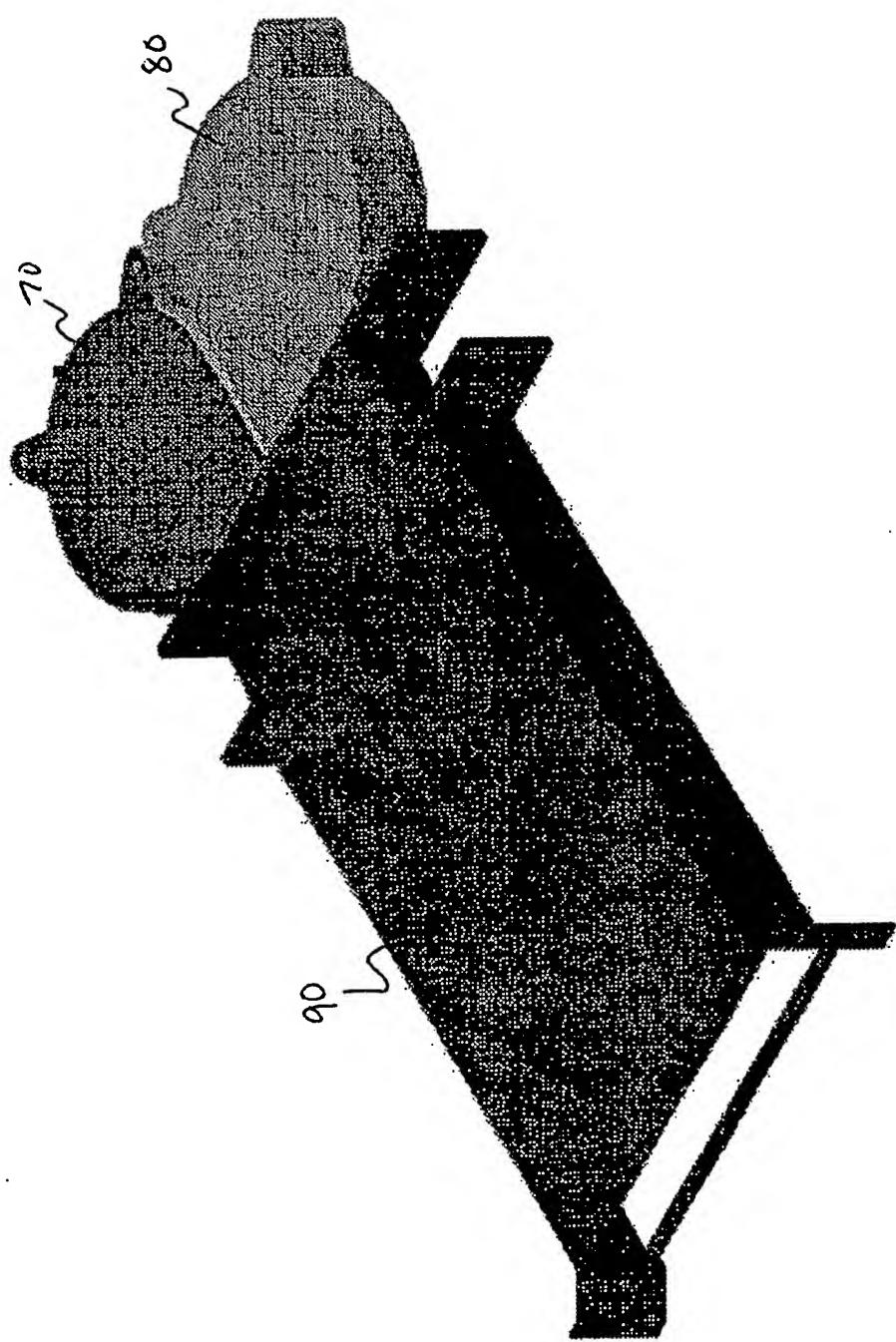


FIGURE 2

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4/7

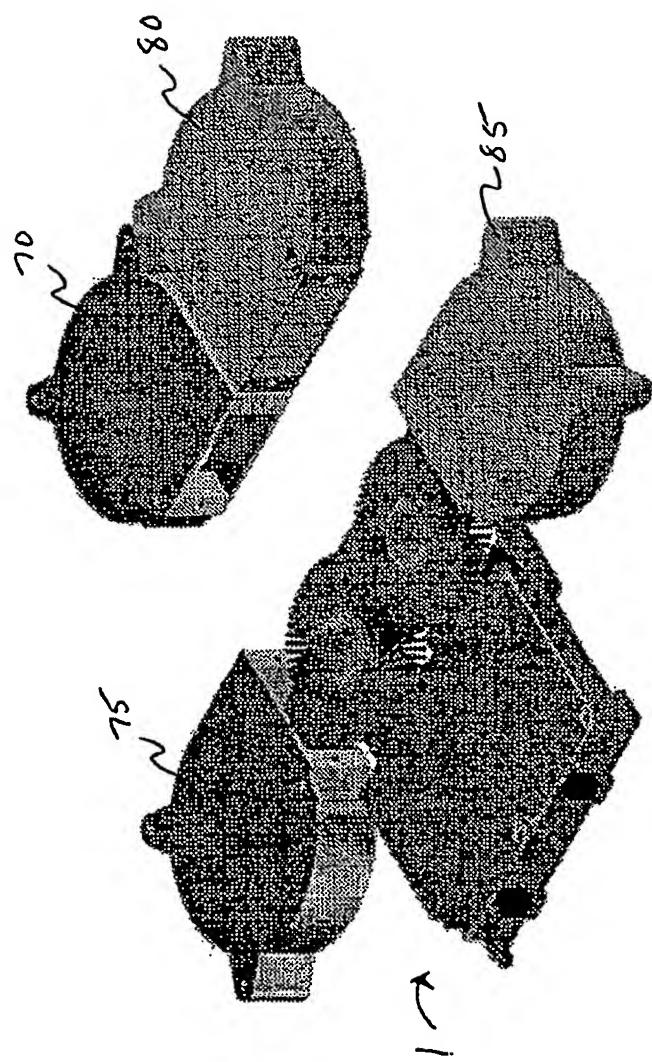


FIGURE 4

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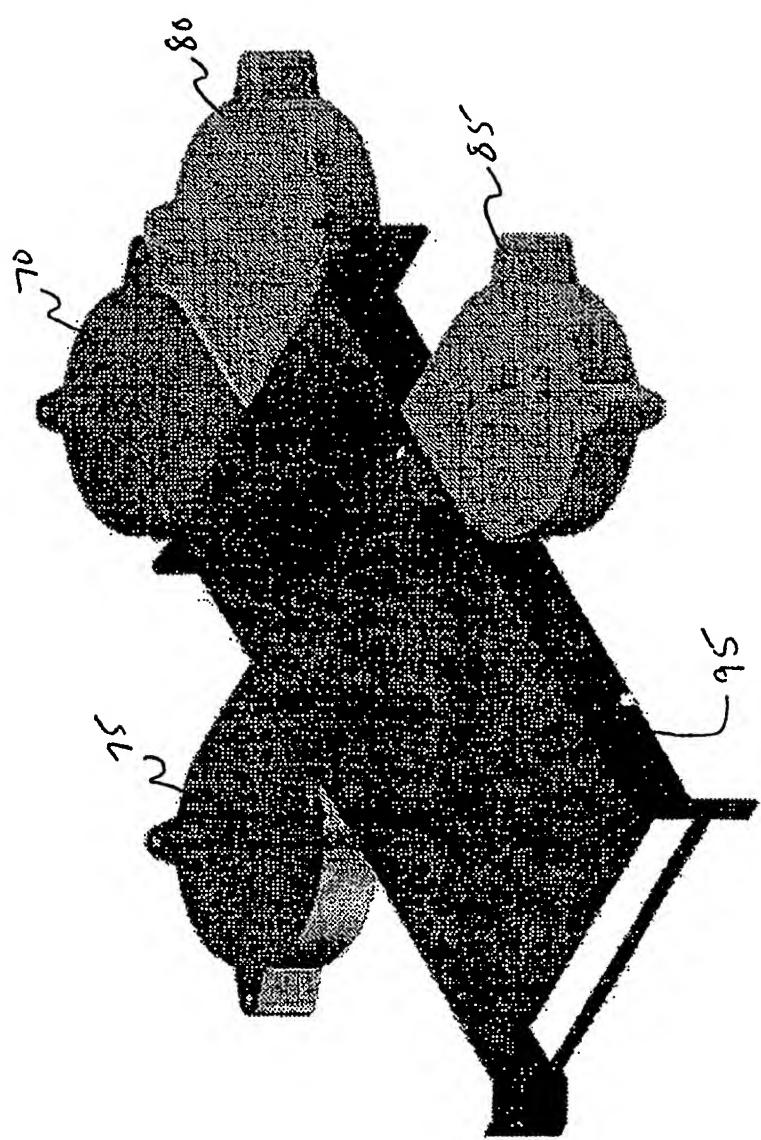


FIGURE 5

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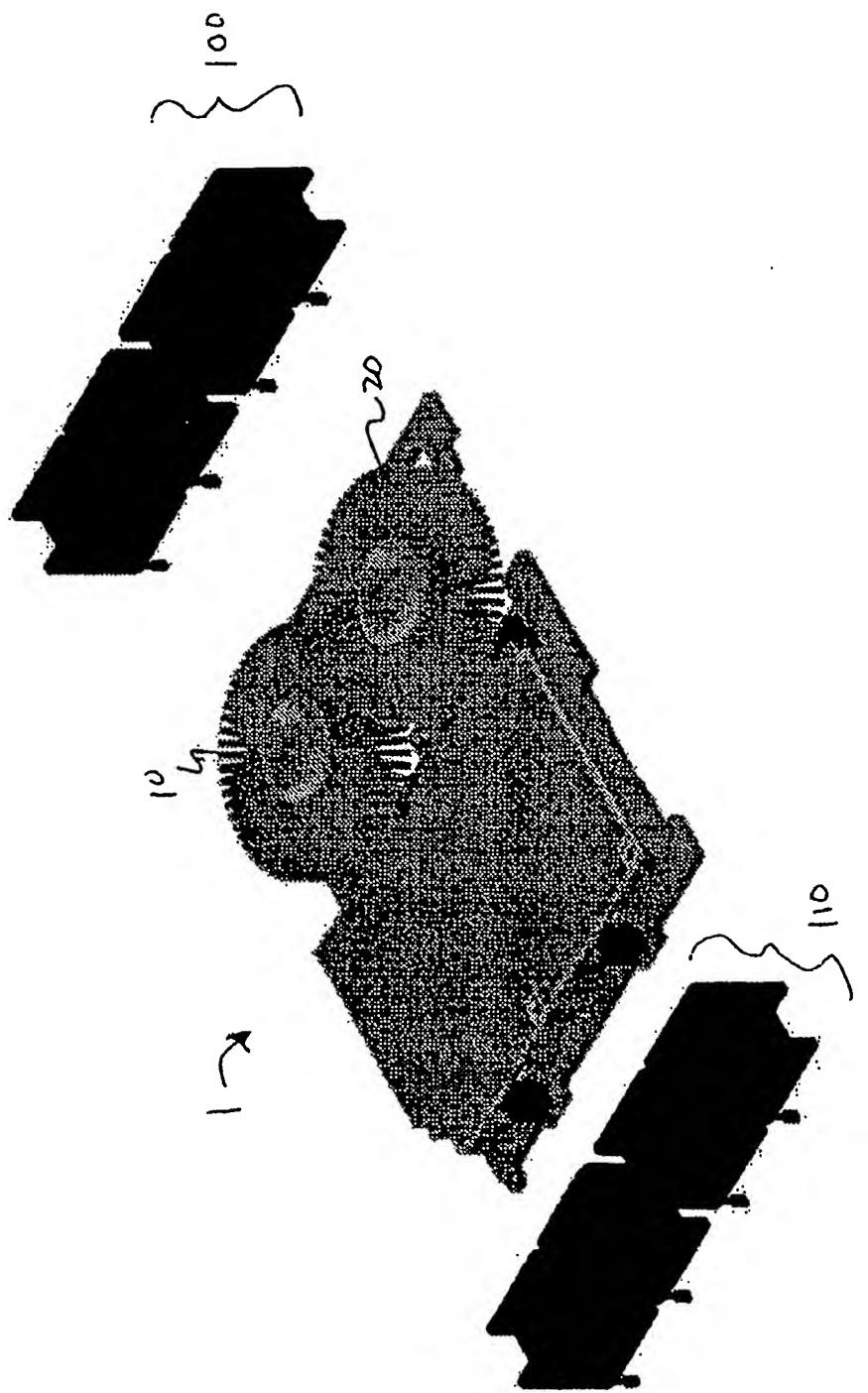


FIGURE 6

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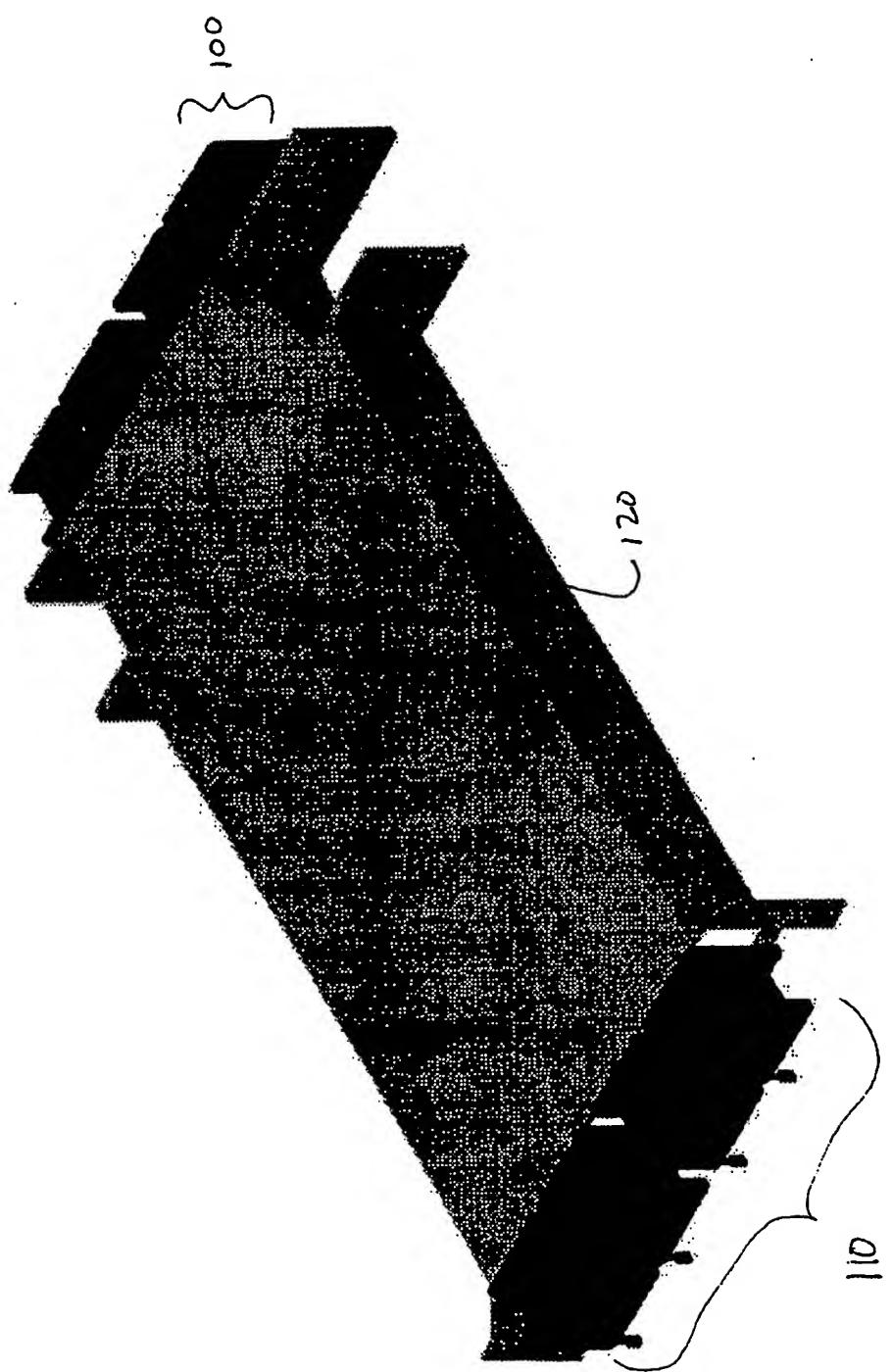


FIGURE 7

## INTERNATIONAL SEARCH REPORT

Internal	Application No
PCT/US 02/31628	

A. CLASSIFICATION OF SUBJECT MATTER		
IPC 7	H05K7/20	H01L23/467

According to International Patent Classification (IPC) or to both national classification and IPC
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B. FIELDS SEARCHED
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Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H05K H01L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
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Electronic data base consulted during the International search (name of data base and, where practical, search terms used)
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EPO-Internal
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C. DOCUMENTS CONSIDERED TO BE RELEVANT
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Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 702 405 A (MOTOROLA INC) 20 March 1996 (1996-03-20) column 2, line 11 - line 24; figure 1 column 3, line 3 - line 24; figure 4	1-6, 12, 15
X	DE 199 08 160 A (SIEMENS AG) 7 September 2000 (2000-09-07) column 5, line 40 - line 53; figure 1	1, 5, 7-10
X	GB 2 354 316 A (LUCENT TECHNOLOGIES INC) 21 March 2001 (2001-03-21)  page 3, line 1 - line 27; figure 1	1, 2, 9-11, 17, 18
X	US 6 179 046 B1 (WONG CHEN-JOW ET AL) 30 January 2001 (2001-01-30) column 2, line 33 -column 3, line 38; figures 1A, 1B, 3A	1, 5-7, 9, 10
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Date of the actual completion of the International search	Date of mailing of the International search report
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6 March 2003	13/03/2003
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Rubenowitz, A
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Intern'l Application No  
PCT/US 02/31628

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